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Intelligent Estimation of Total Suspended Solids (TSS) in Wastewater Treatment Plants Utilizing Non-Liner Regression Analysis

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Abstract

The hazardous pollutants in industrial wastewater could risk the ecosystem at danger if it is not properly treated. Industrial wastewater, which contains more pollution than municipal wastewater, is a major part of the wastewater produced in modern countries. Monitoring the physico-chemical parameters such as total suspended solids (TSS) in wastewater treatment plants could reduce environmental impacts; however, it could be laborious and time consuming. Therefore, using intelligent models for measuring these parameters could simplify and expedite the procedures. In this study, the amount of the facile measure total dissolved solids (TDS) was evaluated by using electrical conductivity (EC) conversion, and then the amounts of total solids (TS) and total suspended solids (TSS) were calculated by statistical and regression analysis.

Keywords: *Intelligent Modelling; Total Suspended Solids; Regression Analysis*

INTRODUCTION

Managing the water and wastewater is among the primary affairs containing a considerable challenge in the most of populated countries [1]. In context of the Water Framework Directive (WFD), safeguarding water resources will be crucial in future [2]. By monitoring water bodies, the WFD aims to maintain appropriate water quality in all continental waterways [3]. Additionally, according to the WFD, the ecological condition of surface waters is determined using an integrated assessment method that takes into account hydrological, physicochemical, and biological criteria [4]. Data on the status of aquatic ecosystems are provided by each quality metric in a different way [5]. The development of the latest treatment techniques as well as the upgrade of current systems is now driven by global population changes as well as recent strict laws for wastewater treatment plants (WWTPs) [6]. Furthermore, different alternatives for WWTPs have varying levels of effectiveness at different therapeutic levels, and as a result, variable direct environmental effects [7]. These factors need thorough environmental assessments inside wastewater treatment plants in order to fulfil particular treatment requisites with respect to environmental consequences [8].

Additionally, wastewater treatment technology needs to be developed to lessen the impact of eliminating untreated wastewater on the environment [9]. Different wastewater treatment methods have different effective characteristics, and they also have different direct effects on the environment [10]. Most wastewater treatment facilities use a lot of energy, and some of their systems require a lot of space [11]. Furthermore, wastewater evacuation without proper treatment may cause environmental pollution and endanger human life [12]. The industrial zones shall be established in a way that minimize environmental concerns. For instance, industrial wastewater production is a massive issue, which should be removed [13]. Accordingly, it can be said that wastewater treatment is essential affair and to satisfy environmental standards; the performance of treatment plants must be evaluated constantly due to the changeable nature of parameters [14]. It is important to measure inputs and manage the effluent quality of treatment plants properly. Some of the parameters that use to evaluate the performance of treatment plants are biological Different wastewater treatment methods have different efficiency characteristics, and they also have different direct effects on the aquatic environment. Oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS), total dissolved solids (TDS) and PH.

Importance of the proper monitoring of the wastewater characteristics due to environmental concerns has increased the demand for the facile and feasible procedures for measuring wastewater parameters. Moreover, there are difficulties with sludge sedimentation and bacterial analysis which increase the necessity of developing other evaluating parameters than sludge volume index (SVI) and total suspended solids (TSS). Furthermore, various sedimentation values comprising sludge quality index (SQI), diluted sludge volume index (DSVI), initial sedimentation velocity (ISV), stirred specific volume index (SSVI), and modified sludge index (IVF) require meticulous dilution and elaborative instrument to measure. Accordingly, utilization of the proper intelligent models for measuring these parameters could contribute to the better monitoring of the wastewater parameters and consequently increase a quality of effluent. Likewise, Mungray and Patel studied on wastewater entering USAB and ASP systems to find a relationship between TSS parameter with total coliforms (TC) and faecal coliforms (FC) [15]. Kazmi et al. evaluated the active sludge systems in different cities in India and the amount of correlation coefficient (R2) between TSS parameters with TC and FC were 0.72 and 0.75, respectively. In this study, mathematical and statistical models, especially regression methods, are used to estimate the EC conversion factor to TDS in different seasons and to predict the amount of total suspended solids (TSS) in raw sewage to treatment plants of Tous Industrial Zone, Mashhad, Iran.

MATERIAL AND METHODS

The method used in this study are divided into three sections such as statistical data collection, mathematical calculation and designing prediction models. The method of data collection is based on the statistical obtaining the real data from the wastewater treatment plant and mathematical analysis according to the following sections:

Statistical studies of wastewater treatment plant

In this part, the results of practical experiments performed at Tous wastewater treatment plant (WWTP) were collected, classified and verified. EC values were collected at the different temperature and various season of the year. The data were then used for calculation of the dependent variables in the WWTP.

Calculating the EC conversion factor to TDS

According to studies by Metcalf and Eddy, there is always a logical relationship between EC and TDS described in equation 1 [16]. According to the equation 1, the TDS has a direct temperature-dependent correlation with the collected EC.

$$TDS = K * EC$$

$$0.55 \leq K \leq 0.9 \text{ (in T= 25 °C)}, K = F \text{ (Temperature °C)} \quad (1)$$

Designing TSS prediction models

Functions are designed to predict the raw sewage TSS, using regression analysis and fitting curves. There is no logical relationship between TDS (calculated from EC) and TSS but this relationship can be noticed between TS and TDS as well as TS and TSS. Therefore, TS and TSS can be predicted by EC determination.

RESULTS AND DISCUSSION

Tous Industrial Zone has two entrances related to phases I and II. Results have shown that values of K factor in the entrance of plant phase I in spring, summer and fall are 0.5, 0.49 and 0.61 and for entrance phase II are 0.58, 0.5 and 0.58, respectively. Results of statistical analysis and fitting curves are shown in Figure 1 and Figure 2.

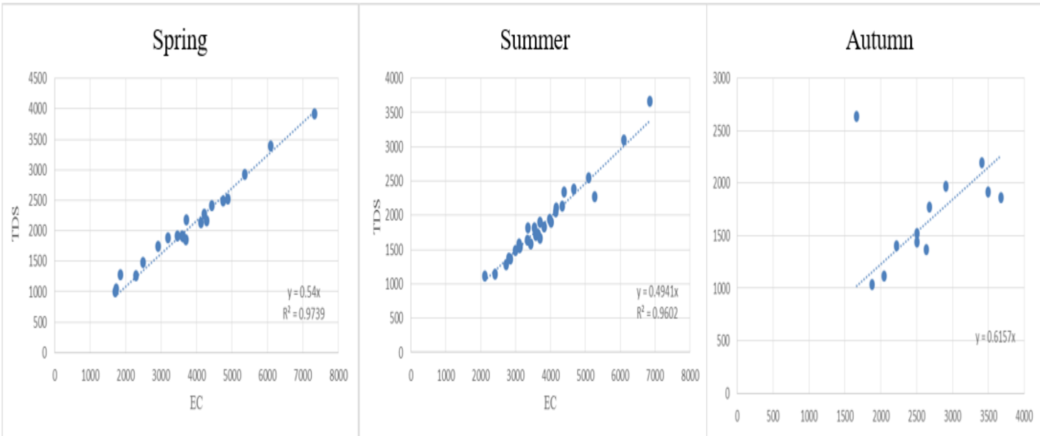

Figure 1. Determining K factor in different seasons for entry I (from left to right: spring, summer, fall)

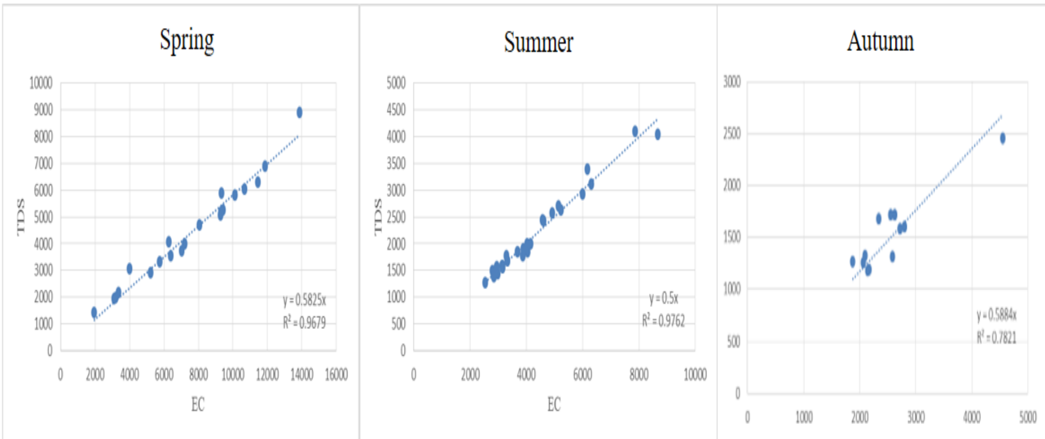

Figure 2. Determining K factor in different seasons for entry II (from left to right: spring, summer, fall)

As it is mentioned, determining the relationship between TS and TDS can only be achieved by measuring the EC of the raw sewage into the plant from entries I and II, then estimate the total solids (TS) and total solids suspensions (TSS), see equation 2.

$$Determine\ EC \longrightarrow TSS_i = TS_i - TDS_i \tag{2}$$

Fourier 8 with R^2=0.67 was used for entry I and Gauss 6 was used for entry II in order to predict the TS from TDS. Designed models for entries I and II are displayed in equation 3 and equation 4, respectively.

$$\begin{gathered}
TS = a_0 + a_1 cos(TDS \times w) + b_1 sin(TDS \times w) \\
+ a_2 cos(2\,TDS \times w) + b_2 sin(2\,TDS \times w) + a_3 cos(3\,TDS \times w) + b_3 sin(3\,TDS \times w) \\
+ a_4 cos(4\,TDS \times w) + b_4 sin(4\,TDS \times w) + a_5 cos(5\,TDS \times w) + b_5 sin(5\,TDS \times w) \\
+ a_6 cos(6\,TDS \times w) + b_6 sin(6\,TDS \times w) + a_7 cos(7\,TDS \times w) + b_7 sin(7\,TDS \times w) \\
+ a_8 cos(8\,TDS \times w) + b_8 sin(8\,TDS \times w) \\
Coefficients\ (95\%\ confidence\ bounds): \\
a_0 = 6.529e+13\ (-7.419e+16, 7.432e+16) a_5 = -5.992e+12\ (-5.314e+15, 5.302e+15) \\
a_1 = -4.699e+13\ (-6.212e+16, 6.202e+16) b_5 = 3.338e+12\ (-6.116e+15, 6.122e+15) \\
b_1 = -1.071e+14\ (-1.18e+17, 1.178e+17) a_6 = 1.279e+12\ (-1.864e+15, 1.866e+15) \\
a_2 = -5.668e+13\ (-5.427e+16, 5.416e+16) b_6 = 9.531e+11\ (-4.295e+14, 4.314e+14) \\
b_2 = 6.166e+13\ (-7.897e+16, 7.91e+16) a_7 = 4.986e+10\ (-7.41e+13, 7.42e+13) \\
a_3 = 4.491e+13\ (-5.43e+16, 5.439e+16)\ b_7 = -2.288e+11\ (-2.765e+14, 2.76e+14) \\
b_3 = 1.529e+13\ (-6.319e+15, 6.35e+15) a_8 = -1.597e+10\ (-1.487e+13, 1.483e+13) \\
a_4 = -1.85e+12\ (-8.777e+15, 8.774e+15) b_8 = 3.49e+09 (-1.392e+13, 1.392e+13) \\
b_4 = -2.075e+13\ (-2.266e+16, 2.262e+16) \\
w = 0.0005383\ (-0.03666, 0.03774) \\
Goodness\ of\ fit: \\
SSE: 1.023e+07
\end{gathered} \tag{3}$$

$$\begin{gathered}
TS = a_1 exp(-(\frac{TDS-b_1}{c_1})^2) + a_2 exp(-(\frac{TDS-b_2}{c_2})^2) \\
+ a_3 exp(-(\frac{TDS-b_3}{c_3})^2) + a_4 exp(-(\frac{TDS-b_4}{c_4})^2) \\
+ a_5 exp(-(\frac{TDS-b_5}{c_5})^2) + a_6 exp(-(\frac{TDS-b_6}{c_6})^2) \\
a_1 = 5223\ (4034, 6412) a_4 = 7765\ (-3.744e+04, 5.297e+04) \\
b_1 = 2606\ (-1287, 6498) b_4 = 5528\ (1943, 9113) \\
c_1 = 3406\ (-5811, 1.262e+04)\ c_4 = 447.8\ (-2452, 3348) \\
a_2 = 1e+17\ (-1.355e+32, 1.355e+32) a_5 = 2653\ (-1698, 7003) \\
b_2 = 7888\ (-1.246e+14, 1.246e+14) b_5 = 3336\ (3122, 3549) \\
c_2 = 183.5\ (-4.145e+15, 4.145e+15) c_5 = 246.3\ (-92.66, 585.2) \\
a_3 = 7212\ (-3.655e+04, 5.098e+04) a_6 = 5799\ (-5551, 1.715e+04) \\
b_3 = 6295\ (352.8, 1.224e+04) b_6 = 4378\ (4030, 4726) \\
c_3 = 348.6 (-1.234e+04, 1.304e+04) c_6 = 442.9 (-636.2, 1522) \\
Goodness\ of\ fit: \\
SSE: 5.798e+07
\end{gathered} \tag{4}$$

R-square: 0.7021 $Adjusted\ R-square: 0.5653$ $RMSE: 1252$

The necessity of predicting TSS_i is that this factor is an essential part in calculation of USAB, AG and SG systems. TSS_i is very important in estimating the sludge production. Because the 40%-60% of operating costs of each plant are related to sludge processing, the necessity of predicting TSS_i becomes more apparent. According to the relation showed in equation 5, TSS is an important part in sludge treatment [17]. Based on this relation, aeration (one-way airflow) in grit chambers is used to remove the input TSS. Regarding to the capacity of aeration and prediction of the input TSS_i, it is possible to optimize the amount of air exhaustion from the aeration diffusers and required energy.

$$Grit\ Removal \rightarrow Air\ Force \rightarrow Ra.Air\ Force(\frac{kg}{m^3 Air}) \times Air\ (m^3) \rightarrow Kg.TSS_i \tag{5}$$

Relation showed in eq. 6 deals with the percentage of TSS_i removal in the primary settling basin and by estimating the input TSS_i, the daily sludge volume in this tank can also be predicted. However, a significant portion of TSS_i has always been involved in the biological sludge of the UASB aerobic and AG and SG anaerobic systems. Described in relation showed in equation 7. According to the relations above, the amount of sludge produced by TSS can be estimated for sludge condensation, fixation and dewatering process.

$$\% \, TSS \; Removal = \frac{t}{a + bt} \qquad (6)$$
$$a = 0.0075, b = 0.014, t = \text{Hydrolic Retention Time}$$

$$P_{X,TSS} = \frac{QY(S - S_e)}{1 - SRT(K_d)\%85} + \frac{QY(S - S_e)\,K_d\,F_d\,SRT}{1 - SRT(K_d)\%85} + QX_{nbvss} + (TSS_i + TVS_i)Q \qquad (7)$$
$$\frac{VSS}{TSS} = \%85 \text{ (In The Tous Facility)}$$

CONCLUSION

Total suspended solids (TSS) are an important parameter in treatment plants and plays a significant role in estimating the amount of produced sludge, aeration rate of the diffusers and identification of the wastewater indicator bacteria such as total coliforms (TC) and faecal coliforms (FC). Estimating the amount of TSS with easier methods would be a great help for the treatment plants system. This research represented a meaningful correlation between EC and TDS. Furthermore, the amount of TS can be estimated from TDS using statistical and regression analysis and, in the end, TSS can be calculated.

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CONFLICT OF INTERESTS

The authors confirm that there is no conflict of interests associated with this publication.

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